ORDER		8260. RNP

DRAFT

UNITED STATES STANDARD

for

Required Navigational Performance (RNP) Instrument Approach Procedure Construction

DATE

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATIO

FOREWORD

This order establishes policy and provides specific criteria for developing required navigational performance (RNP) based area navigation (RNAV) instrument approach procedures. This order also augments information contained in FAA Orders 8260.3, United States Standard for Terminal Instrument Procedures (TERPS); 8260.19, Flight Procedures and Airspace; 8260.44, Civil Utilization of Area Navigation (RNAV) Departure Procedures; 8260.45, Terminal Arrival Area (TAA) Design Criteria; and 7130.3, Holding Pattern Criteria.

RNP is an emerging tool for the development of more efficient airspace and operations. An aircraft area navigation system developed for RNP operations provides reliable, repeatable, and predictable performance through specific RNP RNAV capabilities and features. One of the key attributes is what will be defined as RNP RNAV containment. RNP RNAV provides a means to meet the requirements of RNP airspace and operations.

The concept of RNP is a significant enhancement in airspace design, use, and management relating to navigation. It was developed by the International Civil Aviation Organization (ICAO) Special Committee on Future Air Navigation Systems (FANS) and is an integral part of the communication, navigation, surveillance, and air traffic management (CNS/ATM) plan envisioned by the Special Committee. Area navigation systems have historically been developed based upon criteria specifying positioning accuracy, cross track deviation accuracy, flight technical error (FTE), airborne sensor error, and ground equipment error for a specific total system error. RNP as envisaged by ICAO in the Manual for RNP is a concept of navigation performance where a navigation performance accuracy value is expected to be achieved 95% of the time by the population of aircraft operating in the airspace. The 95% navigation performance accuracy is based upon the total error consisting of navigation system error, RNAV computation error, display system error, course selection error, and FTE.

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Director, Flight Standards

Service

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CHAPTER 1. GENERAL

1.0 PURPOSE.

These criteria are the FAA standard for developing instrument approach procedures based on required navigation performance (RNP) using area navigation (RNAV) avionics systems. This order, AC 90-RNP, and AC 20-RNP provide the foundation for RNP RNAV instrument flight rule (IFR) operations.

1.1 DISTRIBUTION.

This order is distributed in Washington headquarters to the branch level in the Offices of Airport Safety and Standards and Communications, Navigation, and Surveillance Systems; to Air Traffic, Airway Facilities, and Flight Standards Services; to the National Flight Procedures Office and the Regulatory Standards Division at the Mike Monroney Aeronautical Center; to branch level in the regional Flight Standards, Airway Facilities, Air Traffic, and Airports Divisions; special mailing list ZVS-827, and to special military and public addressees.

1.2 EFFECTIVE DATE.

1.3 BACKGROUND.

The concept of RNP is a significant enhancement to navigable airspace design, use, and management. It was developed by the International Civil Aviation Organization (ICAO) Special Committee on Future Air Navigation Systems (FANS) and is an integral part of the communication, navigation, surveillance, and air traffic management (CNS/ATM) plan envisioned by the Special Committee. RNP RNAV levels address obstacle protection associated with RNP accuracy values. The RNP RNAV level (RNP x, where x=0.3, 1, 2, etc.), when applied to instrument procedure obstacle evaluation areas, is a variable used to determine a segment half-width value; i.e., total width is ± a multiple of the value used to identify the level. RNP RNAV under the provisions of AC 90-RNP, Title; AC 20-RNP, Title; and Order 8260.RNP imposes a value of 2 x RNP Level to assure the probability of an aircraft departing a segment prior to its termination is no greater than 1×10^{-7}. RNP levels are based on the specifications of RTCA DO-236A, Minimum Avionics System Performance Standards for RNP.

1.4 DEFINITIONS.

1.4.1 Approach Surface Baseline (ASBL).

A line aligned to the runway centerline (RCL) that lies in a plane tangent to the earth at the runway threshold. It is used as a baseline reference for vertical measurement of the height of the glidepath and obstruction clearance surfaces (see figure 1-3).

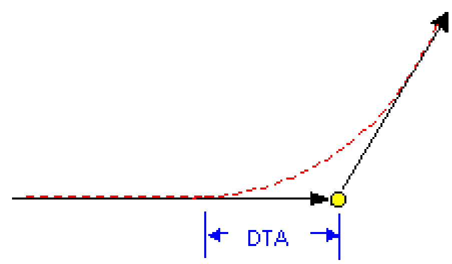
1.4.2 Decision Altitude (DA).

A specified barometric altitude at which a missed approach must be initiated if the required visual references to continue the approach have not been established.

1.4.3 Distance of Turn Anticipation (DTA).

The distance from (prior to) a fly-by fix that an aircraft is expected to start a turn to intercept the course of the next segment (see figure 1-1).

Figure 1-1. DTA



1.4.4 Final Approach Segment (FAS).

The final approach segment begins at the earliest point the precision final approach fix/final approach fix (PFAF/FAF) can be received and ends at the plotted position of the landing threshold point (LTP). The FAS should be aligned with the runway centerline extended.

1.4.5 Fictitious Threshold Point (FTP).

The equivalent of the LTP when the final approach course is offset from runway centerline. It is the intersection of the final course and a line perpendicular to the final course that passes through the LTP. FTP elevation is the same as the LTP (see figure 1-2).

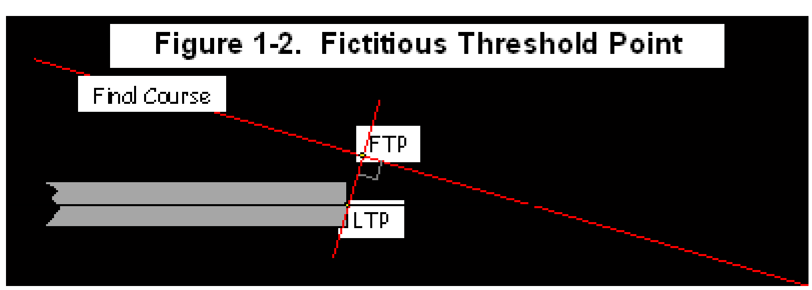
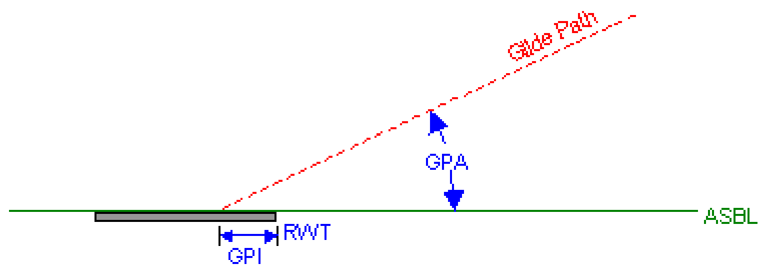


Figure 1-2. Fictitious Threshold Point

1.4.6 Glidepath Angle (GPA).

The angle of the specified final approach descent path relative to the ASBL (see figure 1-3).

Figure 1-3. GPA, GPI



1.4.7 Ground Point of Intercept (GPI).

The glidepath intercepts the ASBL at the GPI. The GPI is expressed as a distance in feet from the runway threshold (see figure 1-3) determined by the formula: $GPI = {TCH}/{\tan(GPA)}$.

1.4.8 Glidepath Qualification Surface (GQS).

The GQS is a narrow inclined plane centered on the runway centerline that limits the height of obstructions between DA and LTP.

1.4.9 Landing Threshold Point (LTP).

The point where the runway center line (RCL) and runway threshold (RWT) intersect. It is defined by WGS 84/NAD 83 latitude, longitude, and orthometric height (mean sea level (MSL) elevation). See figure 1-4.

Figure 1-4. LTP

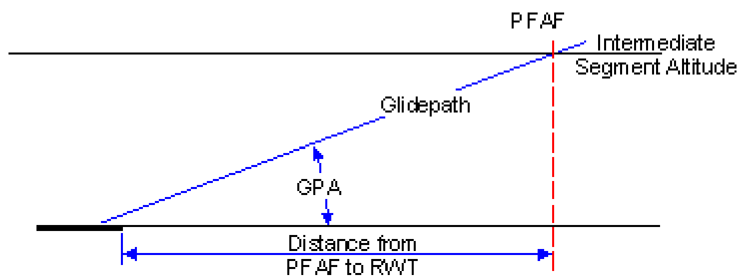
1.4.10 Obstacle Clearance Surface (OCS).

An inclined surface associated with the glidepath angle of a precision approach or an approach procedure with vertical guidance (APV). The separation between this surface and the vertical path angle at any given distance from GPI defines the MINIMUM required obstruction clearance at that point.

1.4.11 Precision Final Approach Fix (PFAF).

A 2-dimensional (2D) point located on the final approach where the GPA intercepts the intermediate segment altitude (glidepath intercept altitude). The PFAF marks the plotted position of the beginning of the precision final segment (see figure 1-5).

Figure 1-5. PFAF



1.4.12 Required Navigation Performance (RNP).

RNP is a measurement of lateral accuracy in navigational performance specified in nautical miles. It represents a 95% per flight hour probability that an aircraft will remain in the defined airspace.

1.4.13 RNP Area Navigation (RNP RNAV).

RNP RNAV is navigation to a specified level of accuracy. This level is associated with a value used in Order 8260.3B, United States Standard for Terminal Instrument Procedures (TERPS), to define the lateral confines of the airspace in which RNP RNAV certified aircraft operate. The value represents a 1×10^{-7} probability per approach that aircraft certified under the standards contained in RTCA DO-236 will remain with designated obstruction protection areas.

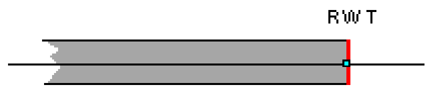
1.4.14 Required Obstacle Clearance (ROC).

This value is the minimum measure of obstacle clearance that is considered by the FAA to supply a satisfactory level of vertical protection. ROC is provided through application of level and sloping OCS.

1.4.15 Runway Threshold (RWT).

The RWT marks the beginning of that part of the runway usable for landing (see figure 1-6). It extends the full width of the runway. The RWT geographic coordinates identify the point the runway centerline crosses the RWT.

Figure 1-6. Threshold



1.4.16 Visual Glide Slope Indicator (VGSI).

The VGSI is an airport lighting aid that provides the pilot a visual indication of the aircraft position relative to a specified glidepath to a touchdown point on the runway. This guidance is generated by radiating a directional pattern of high intensity red and white focused light beams to indicate to the pilot that he is "on path" if he sees red/white, "above path" if white/white, and "below path" if red/red.

1.5 INFORMATION UPDATE.

Any deficiencies found, requests for clarification, or suggested improvements regarding the content of this order must be forwarded for consideration to:

DOT/FAA

Flight Procedure Standards Branch, AFS-420

P.O. Box 25082

Oklahoma City, OK 73125

1.5.1 Your Assistance is Welcome.

FAA Form 1320-19, Directive Feedback Information, is included at the end of this order for your convenience.

1.5.2 Other Comments Block.

Use the "Other Comments" block of this form to provide a complete explanation of why the suggested change is necessary.

CHAPTER 2. GENERAL CRITERIA

2.0 POLICY DIRECTIVES.

Orders 8260.3, United States Standard for Terminal Instrument Procedures (TERPS); 8260.19, Flight Procedures and Airspace; 8260.44, Civil Utilization of Area Navigation (RNAV) Departure Procedures; 8260.45, Terminal Arrival Area (TAA) Design Criteria; and 7130.3, Holding Pattern Criteria, apply unless specified in this order. The final and missed approach criteria described in this order supersedes the other publications listed above, except as noted.

2.1 DATA RESOLUTION.

Perform calculations with a level of precision of at least 0.01 unit of measure accuracy. Document World Geodetic System (WGS) 84/North American Datum (NAD) 83 latitudes and longitudes to the nearest one hundredth (0.01) arc second; mean sea level (MSL) and above ground level (AGL) elevations to the nearest hundredth (0.01) foot; tracks, courses, GPA's to the nearest one-hundredth (0.01) degree, and distances to the nearest hundredth (0.01) unit.

2.1.1 Mathematics Convention.

2.1.1 **a. Definition of Mathematical Functions.**

$a+b$ indicates addition

$a-b$ indicates subtraction

$a \times b$ or ab indicates multiplication

$\frac{a}{b}$ or a/b or $a \div b$ indicates division

$(a-b)$ indicates the result of the process within the parenthesis

$|a-b|$ indicates absolute value

$\approx$ indicates approximate equality

$\sqrt{a}$ indicates the square root of quantity "a"

a^2 indicates $a \times a$

$\tan(a)$ indicates the tangent of "a" degrees

$\tan^{-1}(a)$ indicates the arc tangent of "a"

$\sin(a)$ indicates the sine of "a" degrees

$\sin^{-1}(a)$ indicates the arc sine of "a"

$\cos(a)$ indicates the cosine of "a" degrees

$\cos^{-1}(a)$ indicates the arc cosine of "a"

2.1.1 **b. Operation Precedence (Order of Operations).**

First: Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.

Second: Functions: Tangent, sine, cosine, arcsine and other defined functions

Third: Exponentiations: powers and roots

Fourth: Multiplication and Division: products and quotients

Fifth: Addition and subtraction: sums and differences

e.g,

$5-3\times 2=-1$ because multiplication takes precedence over subtraction

$(5-3)\times 2=4$ because parentheses take precedence over multiplication

$\frac{6^2}{3}=12$ because exponentiation takes precedence over division

$\sqrt{9+16}=5$ because the square root sign is a grouping symbol

$\sqrt{9}+\sqrt{16}=7$ because roots take precedence over addition

$\frac{\sin(30^\circ)}{0.5}=1$ because functions take precedence over division

$\sin\left(30^\circ/0.5\right)=0.8660254$ because parentheses take precedence over functions

Notes on calculator usage:

1. Most calculators are programmed with these rules of precedence.

2. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity.

2.2 RNP RNAV SEGMENT CONSTRUCTION GENERAL INFORMATION.

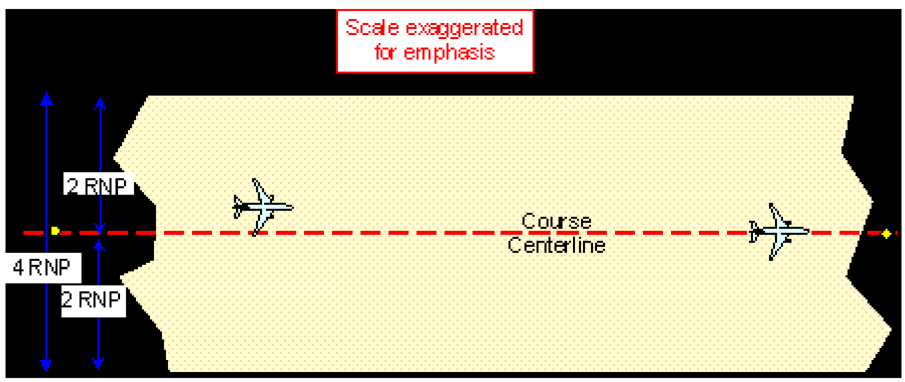
Parallel lines normally bound obstruction clearance areas associated with

RNP-RNAV (see figure 2-1). Segments of differing RNP levels (values) are joined by tapering or expanding the area width as necessary. Turns are normally accomplished at fly-by fixes. Turns are limited to 120° or less at and below flight level 190, 70° or less above flight level 190. Turns greater than 120° should be accomplished with a curved route segment.

2.2.1 Segment Width.

An RNP segment primary area is ± 2 RNP wide. There are no secondary areas. See table 2-1 for application of RNP values.

Figure 2-1 RNP RNAV Segment Width



2.2.2 Segment Roc. (Not applicable to the final approach segment)

The ROC varies according to segment type (initial, intermediate, etc.). See figure 2-2 and table 2-1.

Figure 2-2 RNP RNAV Segment ROC

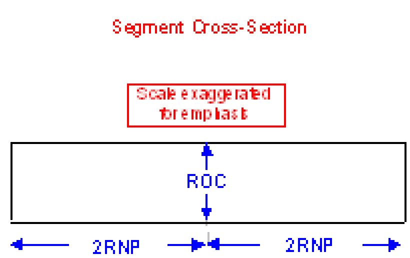


Table 2-1. Typical RNP and ROC Values

SEGMENT	RNP VALUE	ROC VALUE	TOTAL WIDTH
En Route	2.0	1000*	8.0 NM (± 4.0)
Initial	1.0	1000	4.0 NM (± 2.0)
Intermediate	0.3	500	1.2 NM (± 0.6)
Final	0.3	**	1.2 NM (± 0.6)
Missed Approach	1.0	**	4.0 NM (± 2.0)

** 2000 in designated mountainous terrain*

*** Variable for final descent and missed approach climb, see appropriate section.*

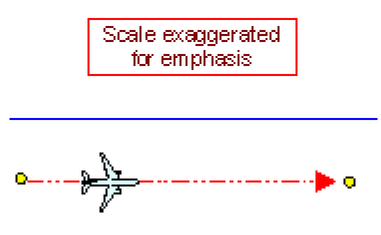
2.2.3 Segment Leg Types.

RNAV segments begin and end at named fixes. RNP procedures are constructed by connecting segment legs together. There are several leg types available for RNAV operations. Five leg types are identified below; however, only two will be utilized in the first edition of these criteria. Additional leg types will be implemented in future changes to this order.

2.2.3 **a. Straight Route Segment [track to a fix (TF) leg].** A straight flight path between two fixes. The first fix is either the previous leg termination fix or the

initial (first) fix of a procedure. The obstruction evaluation area boundaries are parallel lines (see figure 2-3).

Figure 2-3. Track to a Fix (TF) Leg Type



2.2.3 **b. Curved Route Segment [Radius to a Fix (RF) Leg Type]** (see figure 2-4).

A curved route segment prescribes a curved path between two fixes about a defined turn center. A curved route segment is used where a gradual course change is required within the segment. The curved segment begins tangent to the previous segment course at its terminating fix and ends tangent to the

follow-on course at its beginning fix. The obstruction evaluation area boundaries are parallel lines. The MINIMUM radius is 4 NM.

NOTE: The radius of the curved route directly affects the bank angle of the aircraft. RF legs should not be used unless operationally necessary. Most turns should be accomplished as fly-by, giving the aircraft avionics the opportunity to define the optimum turn.

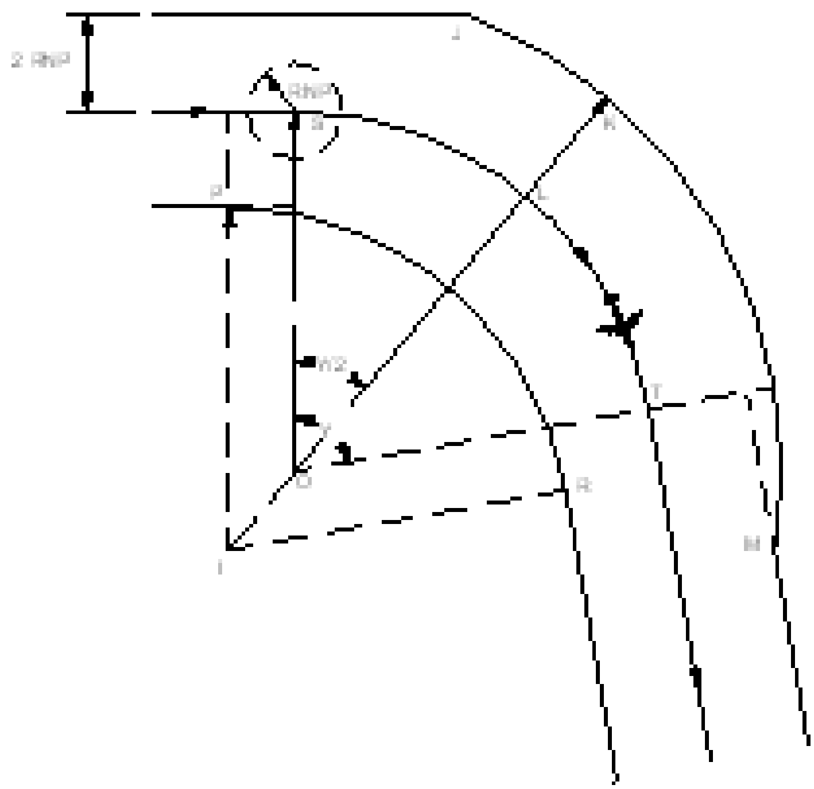
Construct the obstacle clearance areas as follows: For the straight segments preceding and following the turn, the half width is equal to 2 RNP (see

table 2-1). Referring to figure 2-2, locate point "O" at a distance of "r" perpendicular from the point "S" on the straight course where the turn commences. Point "O" is the center of the RF turn and "Y" is the angle of turn. Locate point "T" at the point the straight course following the turn is perpen-dicular to a line from point "O". Draw a line that makes an angle of Y/2 with the perpendiculars to the straight segments. This line intersects the RF turn at point "L". On the same line, place the point "K" such that LK = 2.828 RNP.

{ Derived from LK = (2RNP) ÷ (cos(45°)); since 1 ÷ cos(45°) = 1.414 then LK = 2.828 RNP }

Determine the outer primary area boundary radius, using "O" as an origin, draw an arc with a radius equal to OK (r+2.828 RNP) from "J" to "M", where they join the outer boundary lines of the primary area for the straight segments. Determine the inner primary area boundary by locating point "I" on an extension of the bisector line of angle "Y" at a distance equal to 2.818 RNP from point "O". Draw a perpendicular line from point "I" to the nominal track before the turn, which intersects the boundary of the primary area at point "P." Draw an arc centered on point "I," from point "P" to point "R."

Figure 2-4. Constant Radius to A Fix (RF) Turn



2.2.3 **c. Hold to Fix (HF) Route Segment.** RESERVED

2.2.3 **d. Hold to Altitude (HA) Route Segment**. RESERVED

2.2.3 **e. Hold to Manual (HM) Terminal Route Segment.** RESERVED

2.2.4 FLY-BY Fix Turn Inner Boundary Expansion, Outer Boundary Reduction.

RNAV turns are usually accomplished at fly-by, fly-over, or RF leg fixes. Fly-over fixes are not compatible with RNP segments. RF turns do not require turn expansion areas. Turns at fly-by fixes require an expanded area on the inside of the turn to protect the ground track inside the fix (see figure 2-5).

STEP 1: Using the appropriate turn radius from table 2-2, draw an arc tangent to the course to and from the turn fix.

STEP 2: Using the arc origin from step 1, draw an arc of radius r+2 RNP tangent to the outer boundary line of the preceding and succeeding segments.

STEP 3: Using a radius of r+RNP, draw an arc tangent to the inner boundary line of the preceding and succeeding segments.

Figure 2-5. Turn Anticipation at a Fly-By Turn Fix

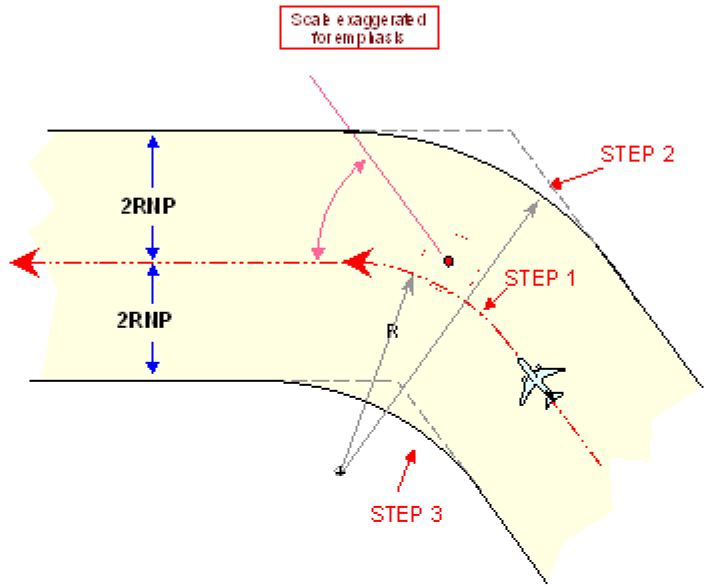


Table 2-2. Radius Value for

DTA Determination

Aircraft Category	A	B	C	D	E
R=	1.2	1.5	1.7	2	2.5

2.2.5 Joining Segments of Differing RNP Values.

RNP values change at specified fixes. Where the RNP changes to a smaller value, the segment boundary tapers inward from the latest point the fix can be received at a rate of 30° relative to course. Locate fixes so the taper to the new value will be completed at least one mile prior to the next navigation fix.

{ When entering a segment with a smaller RNP value, the narrowing taper provides protection for an aircraft that is close to the segment boundary to correct closer to the route centerline in order to remain within the smaller RNP containment area. When entering a segment with a larger RNP value, the expanding taper ensures conservation of airspace required for the transition to a larger RNP value. }

2.2.5 **a. Changing to a Smaller RNP level along a Straight Course (see**

figure 2-5A).

Where the subsequent segment is a smaller RNP level, taper the segment after passing the fix identifying the RNP change. The tapered segment extends from the fix identifying the RNP change plus fix error (**AB** line) to a line (**CD** line) perpendicular to course at distance "d" from the **AB** line.

STEP 1: Locate points **A** and **B** abeam the latest point the fix can be received.

STEP 2: Locate points **C** and **D** on the boundary line distance "d" from the **AB** line.

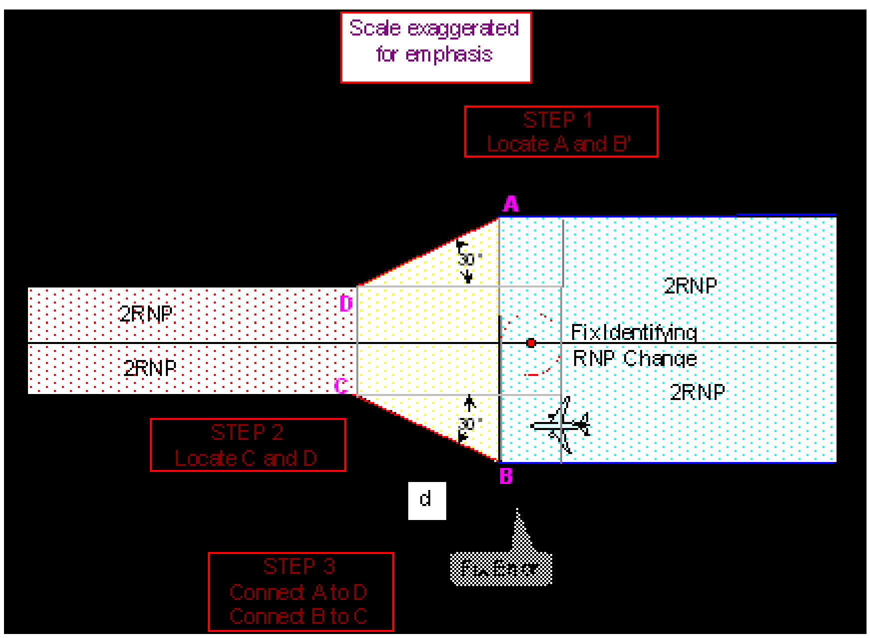
$$d = \frac{2(L-S)}{\tan(30^\circ)} \text{ where d is in NM, L is the larger RNP level, S is the smaller RNP level}$$

$$\text{Example: } \frac{2(1.0-0.3)}{0.577350} = 2.42\text{NM}$$

STEP 3: Connect points **A** to **D** and **B** to **C**.

Figure 2-5A. Changing to Smaller RNP Values

on A Straight Segment



2.2.5 **b. Changing to a Larger RNP level along a Straight Course (see**

figure 2-5B).

If the subsequent segment is a larger RNP level, expand the segment prior to reaching the fix identifying the RNP change.

STEP 1: Establish an imaginary line perpendicular to the course 1× Smaller RNP prior to the fix identifying the RNP change. Locate points **C** and **D** where the line crosses the boundary.

STEP 2: Establish an imaginary line perpendicular to course "d" NM from the CD line. Locate points **A** and **B** where the line crosses the boundary lines.

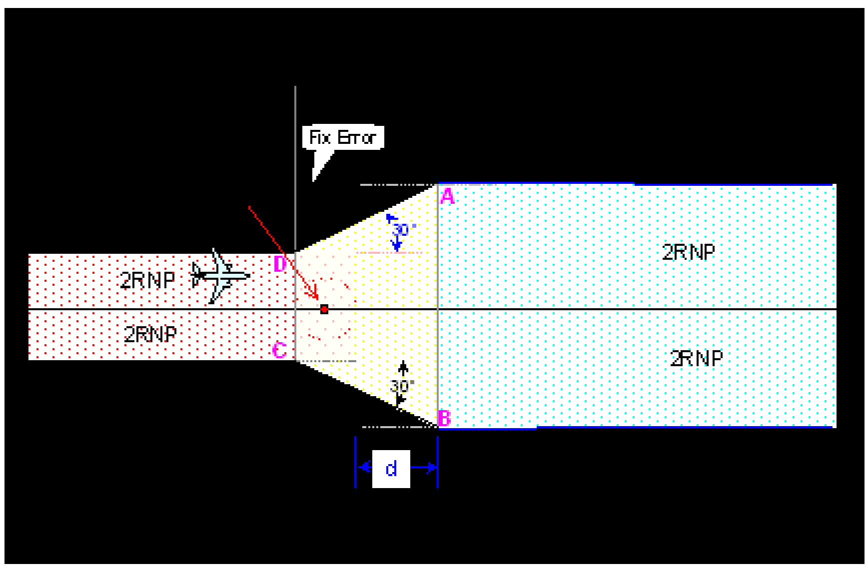
$$d = \frac{2(L-S)}{\tan(30^\circ)} \text{ where d is in NM, L is the larger RNP level, S is the small RNP level}$$

$$\text{Example: } \frac{2(1.0-0.3)}{0.577350} = 2.42\text{NM}$$

STEP 3: Connect points **A** to **D**, and **B** to **C**.

Figure 2-5B. Changing to Larger RNP Values

on A Straight Segment



2.2.5 **c. Changing RNP in an RF Leg**

Changing RNP values within an RF leg is not authorized. Where the leg preceding or following an RF leg is a different RNP value than the RF leg, complete the taper or expansion necessary to accommodate the RF RNP value prior to entering or after leaving the RF leg as appropriate.

2.2.5 **d. Changing RNP levels at a Fly-By Turn Fix** (see figure 2-6).

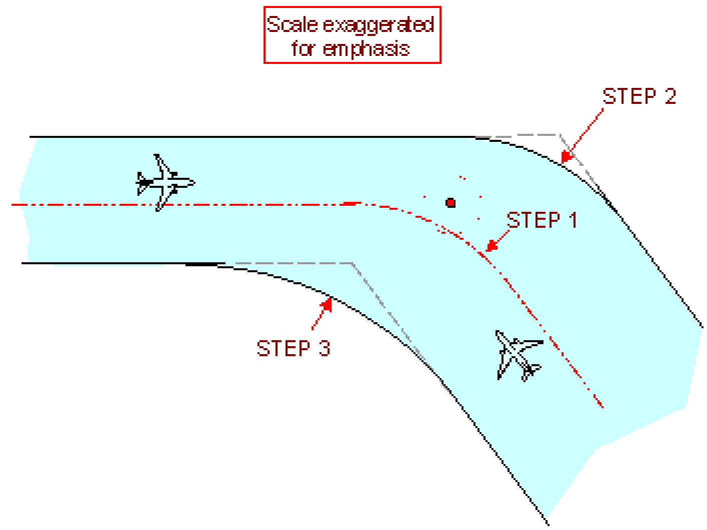
The tapered segment extends from (**B'E'** line) to a line (**C'D'** line) perpendicular to course at distance "d" from the **B'E'** line.

STEP 1: Using the appropriate turn radius from table 2-2, draw an arc tangent to the course to and from the turn fix.

STEP 2: Using the radius from step 1, draw an arc tangent to the outer boundary of the preceding and succeeding segments.

STEP 3: Using the radius from step 1 plus 2 RNP of the larger segment, draw a line tangent to the inner boundary of the preceding and succeeding segments.

Figure 2-6. RNP Change to Lower Value at a Fly-By Turn Fix



CHAPTER 3. EN ROUTE, INITIAL, AND INTERMEDIATE SEGMENTS

3.0 EN ROUTE SEGMENT.

TERPS, Volume 1, paragraph 1718 except "fix" vice "radio fix," paragraph 1719 except secondary areas do not apply, paragraphs 1720, 1730, and 1731 apply except that route width is determined by RNP as described in paragraph 2.2.2.

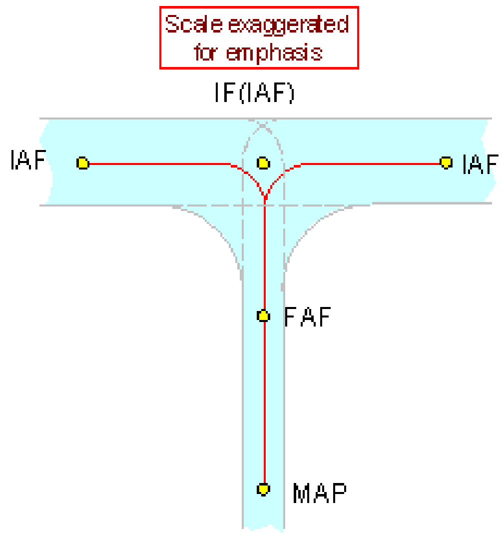
3.1 INITIAL AND INTERMEDIATE SEGMENTS.

3.1.1 Alignment.

The "T" approach configuration (see figure 3-1) is the preferred approach design standard. The intermediate segment must be aligned with the final segment. Refer to Order 8260.45A,Terminal Arrival Area (TAA) Design Criteria, for specific criteria.

{The initial issuance of these criteria does not allow a turn at the final approach fix (FAF). This reflects a conservative approach to assure the safe implementa-tion of RNP application for public approach procedures. Criteria for turn construction at the FAF will be introduced in the first revision to this order.}

Figure 3-1. BASIC T



3.1.2 Length.

The length of the INITIAL segment must accommodate the descent required within the segment. The minimum length of the INTERMEDIATE segment is dependent on the greatest value determined by one of the following factors:

- The distance required to accommodate the tapering of segment width between the initial segment width and the final segment width (see paragraph 2.2.4).
- The magnitude of heading change from the initial course to the intermediate course (see table 3-1).
- The amount of altitude loss required in the segment (see paragraph 3.1.5b).

Table 3-1. MINIMUM INTERMEDIATE COURSE LENGTH

ANGLE (DEGREES)	MINIMUM LENGTH (MILES) Cat A B C D E

90 - 96	3 4 5 6 6
>96 - 102	4 4 5 7 7
>102 -108	4 5 6 8 8
>108 -114	5 6 7 9 9
>114 - 120	5 6 8 10 10

3.1.3 Width.

The width of RNP segments is covered in paragraph 2.2.1 and table 2-1.

3.1.4 Required Obstacle Clearance.

Establish the MINIMUM altitudes in the en route, feeder, initial, and intermediate segments by adding ROC and adjustments to the obstruction elevation, rounding to the nearest 100-foot increment; i.e., round 1,749 feet to 1,700 feet, and round 1,750 feet to 1,800 feet.

3.1.4 **a. En Route Segment ROC.** MINIMUM ROC is 1,000 feet (2,000 feet in designated mountainous terrain).

3.1.4 **b. Initial Segment ROC.** MINIMUM ROC is 1,000 feet.

3.1.4 **c. Intermediate Segment ROC**. MINIMUM ROC is 500 feet.

3.1.5 Descent Angle/Gradient.

The following OPTIMUM and MAXIMUM descent gradients apply. Do not apply MAXIMUM descent gradients in segments of MINIMUM length.

3.1.5 **a. Feeder and Initial Segments**.

- OPTIMUM 250 FT/NM (for high altitude penetrations 800)
- MAXIMUM 500 FT/NM (for high altitude penetrations 1000)

3.1.5 **b. Intermediate Segment.**

- OPTIMUM 150 FT/NM
- MAXIMUM 220 FT/NM.

{Implementation of LNAV/VNAV approach procedures has proven the traditional intermediate segment 318 ft/NM descent gradient limit does

not support a seamless transition to a VNAV final segment. A lesser gradient is required.}

CHAPTER 4. FINAL APPROACH SEGMENT (FAS)

4.0 FAS.

For obstruction clearance purposes, the final approach segment begins at the earliest point the PFAF/FAF can be received and ends at the plotted position of the LTP (see figure 4-3). The FAS should be aligned with the runway centerline extended. If operationally necessary, the FAS may be up to 5° from runway alignment.

{The 5° offset limitation is a conservative implementation policy. Future changes to this document will introduce curved path criteria for complex final approach segment construction.}

4.1 DETERMINING PFAF/FAF COORDINATES (see figure 4-1).

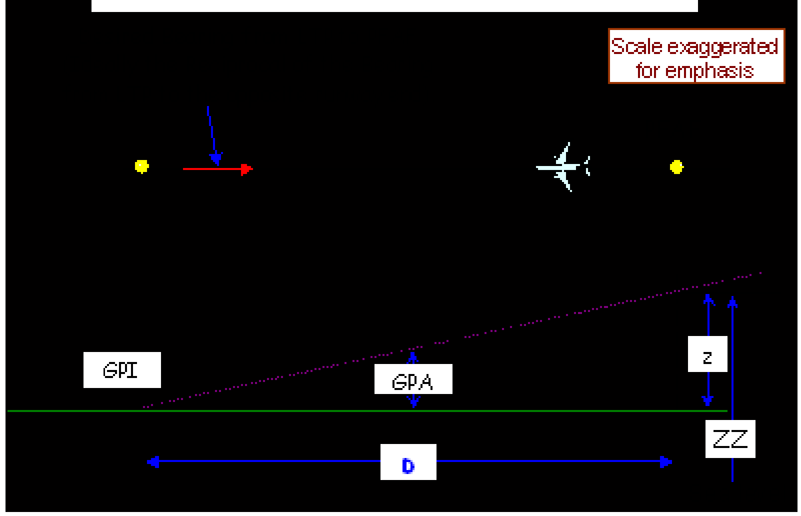


Figure 4-1. Determining PFAF location

Geodetically calculate the latitude and longitude of the PFAF using the true bearing from the LTP to the PFAF and the horizontal distance (**D** - GPI) from the LTP or fictitious threshold point (FTP) to the point the glidepath intercepts the intermediate segment altitude.

Determine **D** using the following formulas:

Step 1: Formula: $z = A - F$

Example: $1537.70 = 2100 - 562.30$

Step 2: Formula: *{includes earth curvature}*

$$D = 364{,}609\left[90 - GPA - \arcsin\left(\frac{20{,}890{,}537 \times \sin(90 + GPA)}{z + 20{,}890{,}537}\right)\right]$$

Example:

$$D = 364{,}609\left[90 - 3 - \arcsin\left(\frac{20{,}890{,}537 \times \sin(90+3)}{1{,}537.7 + 20{,}890{,}537}\right)\right]$$

$$D = 364{,}609\left[87 - \arcsin\left(\frac{20{,}861{,}907.2451}{20{,}892{,}074.70}\right)\right]$$

$$D = 364{,}609[0.0794166528]$$

$$D = 28{,}956.03$$

Where: A = FAF Altitude (example 2100)

F = LTP elevation (example 562.30)

GPA = Glidepath angle (example 3.00°)

4.1.1 Determining Glidepath Altitude at a Fix.

Calculate the altitude (ZZ) of the glidepath at any distance (D) from GPI using the following formula: *{includes earth curvature}*

Formula:

$$ZZ = LTP + \frac{20{,}890{,}537 \times \sin(90 + GPA)}{\sin\left(90 - GPA - \frac{D}{364{,}609}\right)} - 20{,}890{,}537$$

Example:

$$ZZ = 562.30 + \frac{20{,}890{,}537 \times \sin(90+3)}{\sin\left(90 - 3 - \frac{28{,}956.03}{364{,}609}\right)} - 20{,}890{,}537$$

$$ZZ = 562.30 + \frac{20{,}890{,}537 \times 0.9986295347}{0.9985560335} - 20{,}890{,}537$$

$$ZZ = 2{,}100$$

Where: GPA = Glidepath angle (example 3.00°)

D = Distance in feet from GPI to fix

LTP = Threshold elevation (MSL)

ZZ = Glidepath MSL altitude at fix

4.2 THRESHOLD CROSSING HEIGHT (TCH).

Select the appropriate TCH from table 4-1. Publish a note indicating the visual glide slope indicator (VGSI) is not coincident with the RNP procedure GPA when the difference between VGSI angle and the procedure GPA is more than 0.2° or the difference between the VGSI TCH the procedure's TCH is more than 3 feet.

{If an instrument landing system (ILS) serves the runway, use the ILS TCH and glidepath angle.}

Table 4-1. TCH Requirements

Representative Aircraft Type	Approximate Glidepath to Wheel Height	Recommended TCH ± 5 Feet	Remarks
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate Turbojets, T-37, T-38, C-12, C-20, C-21, T-1, Fighter Jets	10 Feet or less	40 Feet	Many runways less than 6,000 feet long with reduced widths and/or restricted weight bearing which would normally prohibit landings by larger aircraft.
HEIGHT GROUP 2 F-28, CV-340/440/580, B-737, C-9, DC-9, C-130, T-43, B-2, S-3	15 Feet	45 Feet	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-135, C-141, C-17, E-3, P-3, E-8	20 Feet	50 Feet	Primary runways not normally used by aircraft with ILS glidepath-to-wheel heights exceeding 20 feet.
HEIGHT GROUP 4 B-747/767/777, L-1011, DC-10, A-300, B-1, KC-10, E-4, C-5, VC-25	25 Feet	55 Feet	Most primary runways at major airports.

Note 1: To determine the minimum allowable TCH, add 20 feet to the glidepath-to-wheel height.

Note 2: To determine the maximum allowable TCH, add 50 feet to the glidepath-to-wheel height.

4.3 GLIDEPATH ANGLE (GPA) (see table 4-2).

Table 4-2. Allowable Range of Glidepath Angles

	Descent Angle	Descent Gradient (FT/NM)
OPTIMUM	3.0°	318

MINIMUM	2.75°	292
MAXIMUM	3.5°	371

4.4 GLIDEPATH QUALIFICATION SURFACE (GQS).

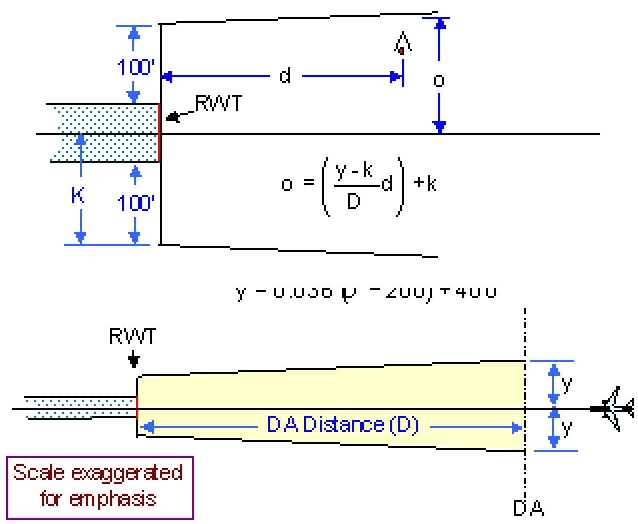
{The GQS limits the height of obstructions between DA and LTP. When obstructions exceed the height of the GQS, an approach with vertical guidance is not authorized.}

4.4.1 Area.

4.4.1 **a. Length**. The GQS extends from the runway threshold to the DA point.

4.4.1 **b. Width**. The GQS originates 100 feet from the runway edge at RWT (see figure 4-2).

Figure 4-2. GQS



Calculate the half width of the GQS at the DA point (y) using the following formula: *{The width of the GQS at DA is equal to the width of the precision "W" surface at DA; therefore, the "W" surface width formula from precision criteria is used.}*

Calculate the half-width of the GQS "o" at any distance "d" from RWT using the following formula:

$$\text{"o" at Distance "d"} = \left(\frac{y-k}{D}d\right) + k$$

Where: D = the distance from RWT to the DA point

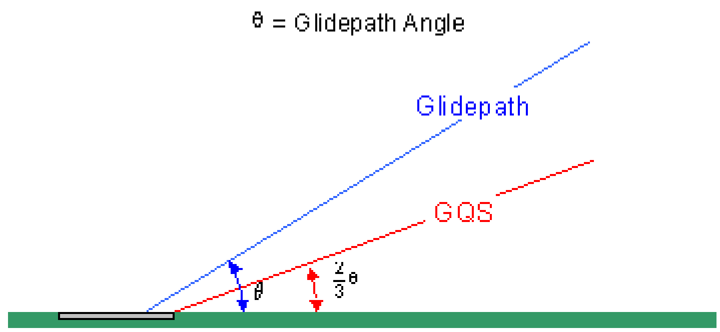
d = the desired distance from RWT

$$k = \frac{\text{RWY Width}}{2} + 100$$

$$y = 0.036(D - 200) + 400$$

4.4.1 **c. Obstacle Clearance Surface (OCS)** (see figure 4-3). Calculate the height of the GQS above ASBL at any distance "d" from RWT using the following formula: *{The GQS rises at an angle that is two thirds of the glidepath angle.}*

Figure 4-3 GQS



$$\text{GQS Height} = \tan\left(\frac{2}{3}\theta\right)d$$

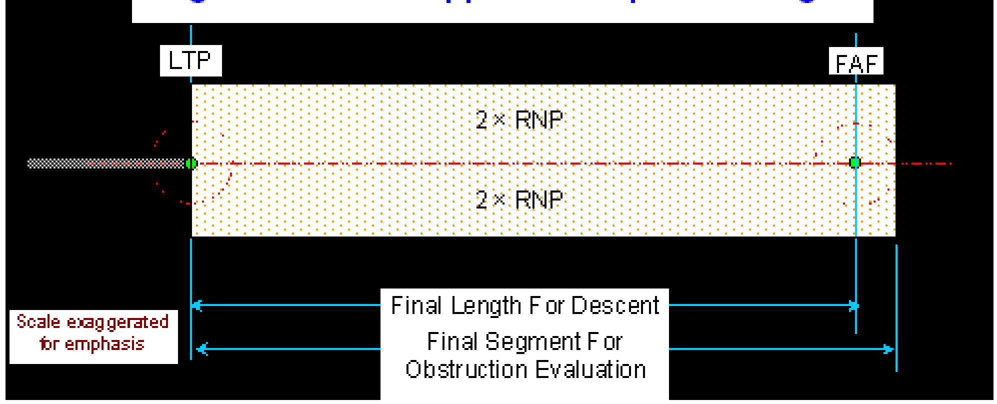
Where: d = the distance from RWT

θ = glidepath angle

4.5 FINAL SEGMENT LENGTH.

The obstruction evaluation area begins at the earliest point the PFAF can be received and extends to the LTP or missed approach point (MAP), whichever is farther (see figure 4-4).

Figure 4-4. Final Approach Trapezoid Length



4.6 FINAL SEGMENT WIDTH.

4.6.1 Primary Area.

Segment width is dependent on the RNP value (see paragraph 2.2.1 for width requirements).

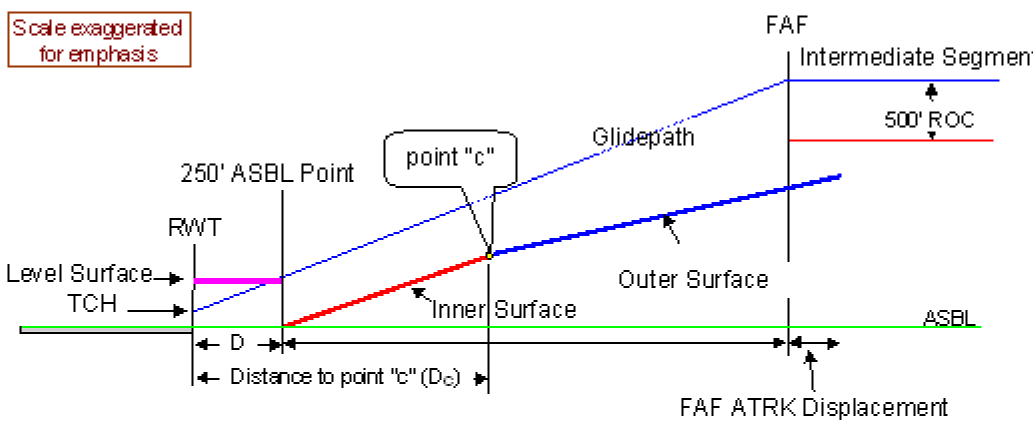
{It is assumed the missed approach RNP will be larger than the RNP required for final approach to account for the possibility of a navigation error alert causing the missed approach initiation. This added width offers protection to aircraft that may have been significantly off route centerline.}

4.7 OBSTRUCTION CLEARANCE.

Obstacle clearance is achieved by applying level and sloping OCS's (see

figure 4-5).

Figure 4-5. Final Segment OCS's

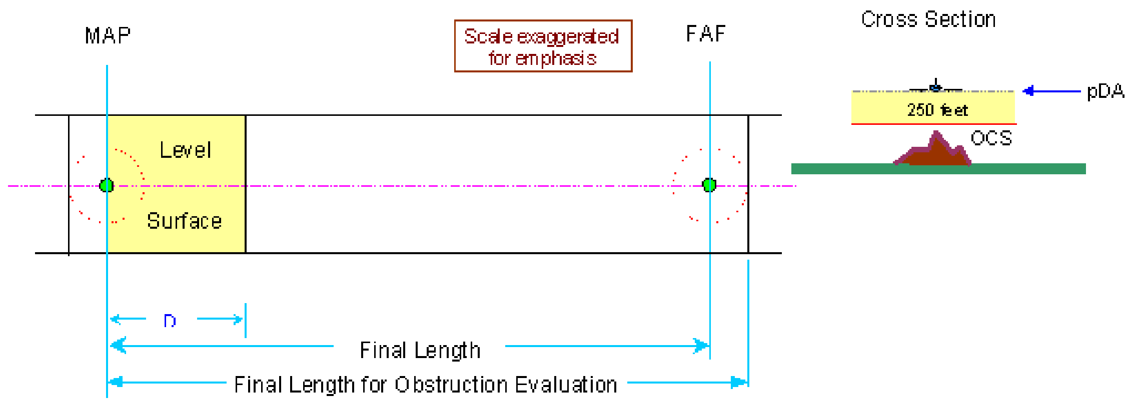


4.7.1 Level Surface.

The longitudinally level OCS overlies the area between the LTP or FTP and the point the glidepath reaches 250 feet above ASBL (distance "D"). See figures 4-5 and 4-6. Calculate distance "D" in feet from the LTP or FTP using the following formula:

$$D = \frac{250 - TCH}{\tan(GPA)} \qquad \text{Example: } \frac{250 - 53}{\tan(3)} = 3{,}758.98'$$

Figure 4-6. Obstacle Clearance Inside The 250 Feet above ASBL Point



4.7.1 **a. Preliminary DA (pDA).** Determine the pDA by adding 250 feet ROC value to the highest obstacle under the level surface.

4.7.2 Sloping Surfaces.

4.7.2 **a. Inner Sloping Surface** (see figure 4-4). The inner surface begins at the point on the ASBL corresponding to the location of the 250 feet above ASBL point (see figure 4-4). The standard temperature deviation from airport ISA temperature is –30° for the contiguous 48 states, -40° for Alaska, and –20° for Hawaii. If you use the standard deviation, skip to step 3. Otherwise, take the following steps to determine the value (S_I) of the inner slope:

STEP 1: Obtain the mean low temperature of the coldest month of the year for the last five years of data. If the data is given in Fahrenheit (°F), convert the temperature to Celsius (°C). Use the following formulae to convert between Celsius and Fahrenheit temperatures:

$$°C = \frac{°F - 32}{1.8} \qquad \text{Example: } \frac{76-32}{1.8} = 24.44°C$$

$$°F = (1.8)(°C) + 32 \qquad \text{Example: } (1.8)(24.44) + 32 = 75.99°F$$

STEP 2: Convert the mean temperature into a deviation from International Standard Atmosphere (ISA) using the following formula, rounding to the lower whole degree:

$$\text{deviation} = °C - \left[15°C - \left(\frac{\text{Airport Elevation}}{500}\right)\right] \qquad \text{Example: } -28 - \left[15°C - \left(\frac{1{,}528}{500}\right)\right] = -39.9°$$

STEP 3: Use this deviation or -15°C, whichever is lower, and the GPA to find the slope value from table 4-3.

STEP 4: Determine the Celsius temperature below which the procedure will not be authorized (T_{NA}). Round the value to the nearest whole degree.

$$T_{NA} = \left[15°C - \left(\frac{\text{Airport Elevation}}{500}\right)\right] - (\text{value from step 3})$$

Table 4-3. S_V Considering GPA and ISA

Temperature Deviation

Glidepath ∠ →	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
ISA (° C) DEV ↓	Slope Values											
-10	23.2	22.4	21.7	21.0	20.4	19.8	19.3	18.8	18.3	17.8	17.4	17.0
-15	23.8	23.0	22.2	21.6	20.9	20.3	19.8	19.3	18.8	18.3	17.9	17.5
-20	24.4	23.6	22.9	22.2	21.5	20.9	20.3	19.8	19.3	18.8	18.4	18.0
-25	25.1	24.3	23.5	22.8	22.1	21.5	20.9	20.4	19.9	19.4	18.9	18.5
-30	25.8	25.0	24.2	23.4	22.8	22.1	21.5	21.0	20.5	20.0	19.5	19.1
-35	26.6	25.7	24.9	24.1	23.4	22.8	22.2	21.6	21.1	20.6	20.1	19.6
-40	27.4	26.5	25.7	24.9	24.2	23.5	22.9	22.3	21.7	21.2	20.7	20.3
-45	28.2	27.3	26.5	25.7	24.9	24.2	23.6	23.0	22.4	21.9	21.4	20.9
-50	29.1	28.2	27.3	26.5	25.8	25.0	24.4	23.8	23.2	22.6	22.1	21.6

4.7.2 **b. Outer Sloping Surface.** The outer surface begins at point "C" and ends at the earliest point the FAF can be received (see figure 4-5). Calculate the distance (D_C) from runway threshold (RWT) or FTP to point C using the following formula:

$$D_C = \frac{(aS_W) - (200S_V)}{(S_W - S_V)}$$

Where a = Distance from RWT or FTP

to OCS origin (D from paragraph 4.7.1.

$$S_W = \frac{102}{VPA}$$

S_V=Slope from table 4-3

4.7.2 **c. Calculating the height of the OCS.**

4.7.2 **c. (1) Inner OCS.** Calculate the height (I_Z) above ASBL of the inner surface using the following formula:

$$I_Z = \frac{D_o - D}{S_V}$$

Where D_o = the distance in feet from the RWT or FTP to the obstacle
D = the distance from the RWT or FTP origin to the inner surface origin

4.7.2 **c. (2) Outer OCS.** Calculate the height (O_Z) above ASBL of the outer OCS using the following formula:

$$O_Z = \frac{(D_o - 200)GPA}{102}$$

4.7.2 **d. Obstacle Clearance Surface (OCS) Penetrations (inner or outer).** Obstructions should not penetrate the OCS. If the OCS's are clear, publish the pDA value as the approach DA. If the OCS is penetrated, take one of the following actions listed in order of preference:

- Remove or adjust the obstruction location and/or height to eliminate the penetration.

• Publish the higher of the pDA or the revised DA determined by the following:

Enter table 4-4 with the deviation value from paragraph 4.7.1 and the height of the penetrating obstruction measured above ASBL and determine the ROC value. Add this value to the obstruction MSL value to arrive at a revised DA value. The published height above threshold (HAT) must be 250 feet or greater.

Table 4-4. BVNAV Required Obstacle Clearance (ROC, Feet)

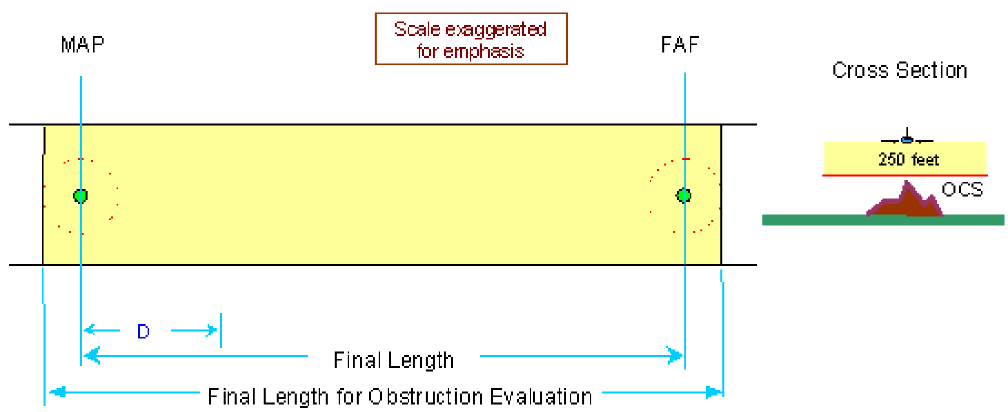
Height Above ASBL→	**250'**	**500'**	**7**
Below ISA At Station↓	**ROC**		

-10	250	250	2
-15	250	250	2
-20	250	250	2
-25	250	250	2
-30	250	250	2
-35	250	250	2
-40	250	250	2
-45	250	250	2
-50	250	250	2

4.7.3 Vertical Guidance Failure (Glidepath Out).

Determine a minimum descent altitude (MDA) for use when vertical guidance fails by applying 250′ ROC and TERPS chapter 3, ROC adjustments to the highest obstruction in the obstacle evaluation area. (see figure 4-7). Round the result to the highest 20-foot increment.

Figure 4-7. Glidepath Inoperative Obstacle Clearance



4.8 MINIMUMS.

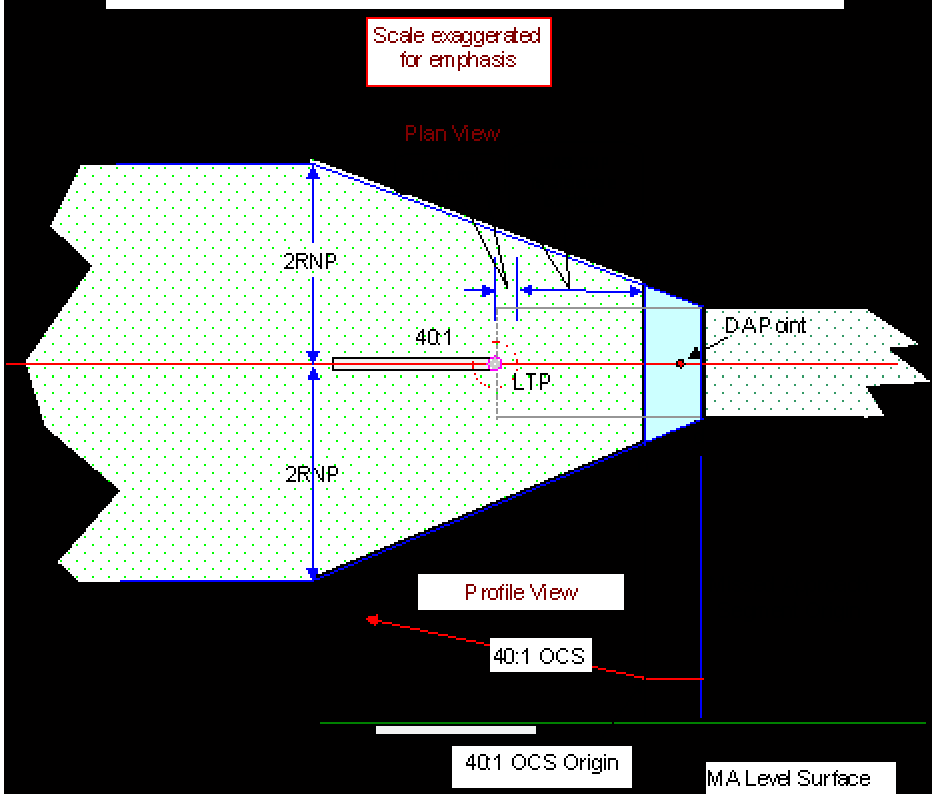
TERPS chapter 3 applies. Use table 9 as applied for localizer final to determine minimum visibility values

CHAPTER 5. MISSED APPROACH SEGMENT (MAS)

5.0 GENERAL.

The MAS extends from the DA point to the missed approach clearance limit (an airway fix or a holding pattern from which an en route transition may be accomplished). Obstacles are evaluated by application of a level surface containing the DA, followed by a 40:1 inclined surface (see figure 5-1). Height loss is assumed after DA. The fix marking the beginning of MAS RNP is normally located at the LTP. The fix may be located prior to the LTP to accommodate early turns. Locate the fix identifying the start of the MAS RNP value change, at least its along-track fix error value subsequent to the ab line (see figure 5-1).

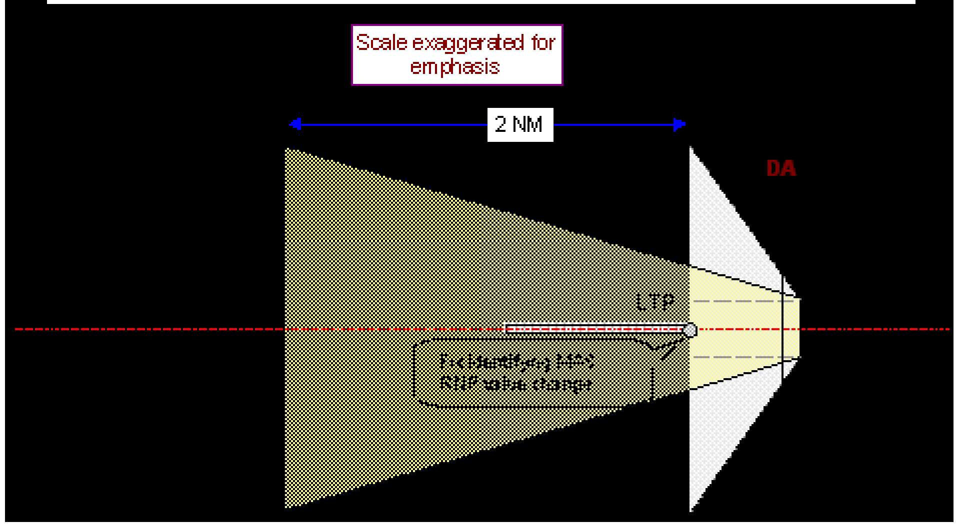
Figure 5-1. Missed Approach OCS



5.1 SEGMENT WIDTH.

The missed approach segment RNP level may be the same as the FAS. Where the MAS RNP level is greater than the FAS, the segment width splays uniformly from FAS width to MAS width. The missed approach boundary normally splays from FAS width at the cd line (figures 5-1 and 5-2) to MAS width at a point 2 NM subsequent to the fix marking the start of the MAS RNP segment (normally the LTP/FTP).

Figure. 5-2 Normal FAS/MAS RNP Transition



5.1.1 Straight Missed Approach Construction.

Straight missed approach segments are constructed using TF leg segments. Where the MAS RNP level is greater than the FAS, the FAS and MAS widths are blended per paragraph 5.1.

5.1.2 Turning Missed Approach.

The missed approach route is a series of segments. Turns are accomplished through application of TF segments connected at fly-by fixes, or RF segments. Where the MAS RNP level is greater than the FAS RNP level, construct turns at or after the point the segment reaches MAS width. Where turns are required prior to the 2 NM splay completion point, the splay may be shortened to end at a point no closer to DA than the fix marking the start of the MAS segment (see figure 5-2). For turns at fly-by fixes, connect successive segments using the criteria in paragraph 2.2.4 (see figure 5-3). For an RF turning segment, the expansion to the MAS RNP must be completed prior to commencing the turn (see figure 5-4). Paragraph 2.2.3 applies.

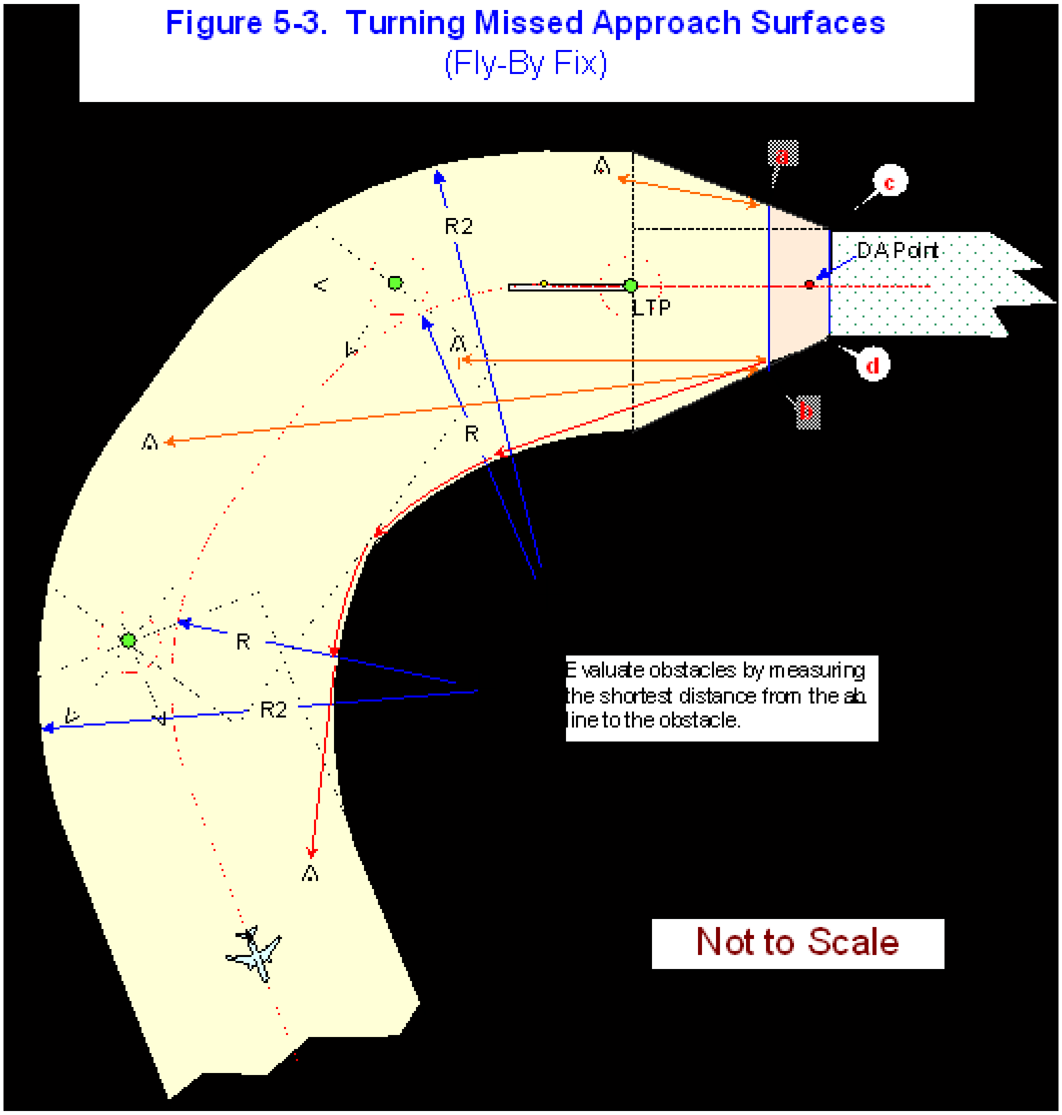
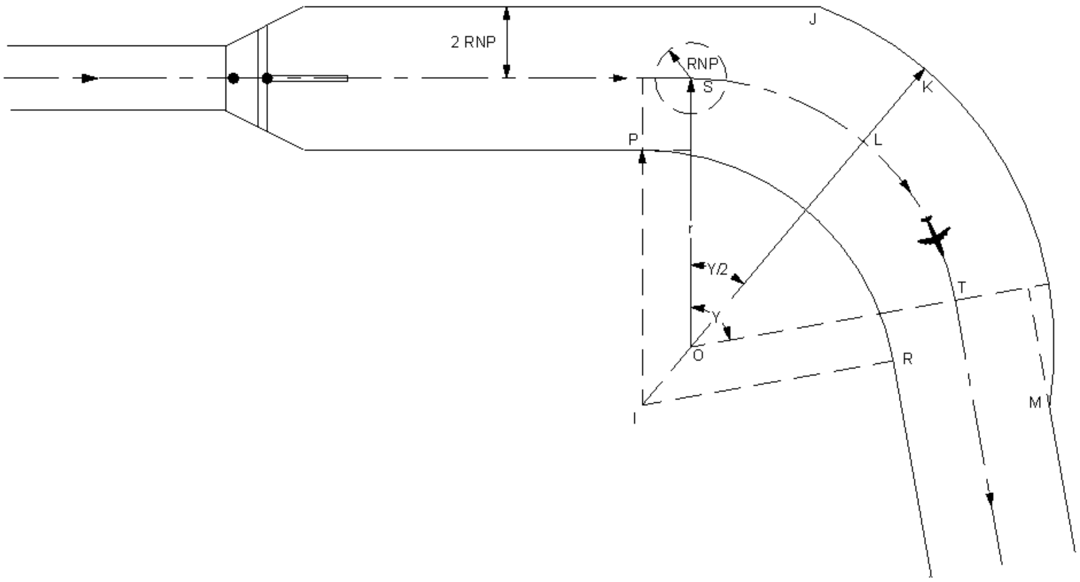


Figure 5-3. Turning Missed Approach Surfaces
(Fly-By Fix)

Figure 5-4 Turning Missed Approach

(TF leg followed by RF leg)



5.2 LEVEL OCS

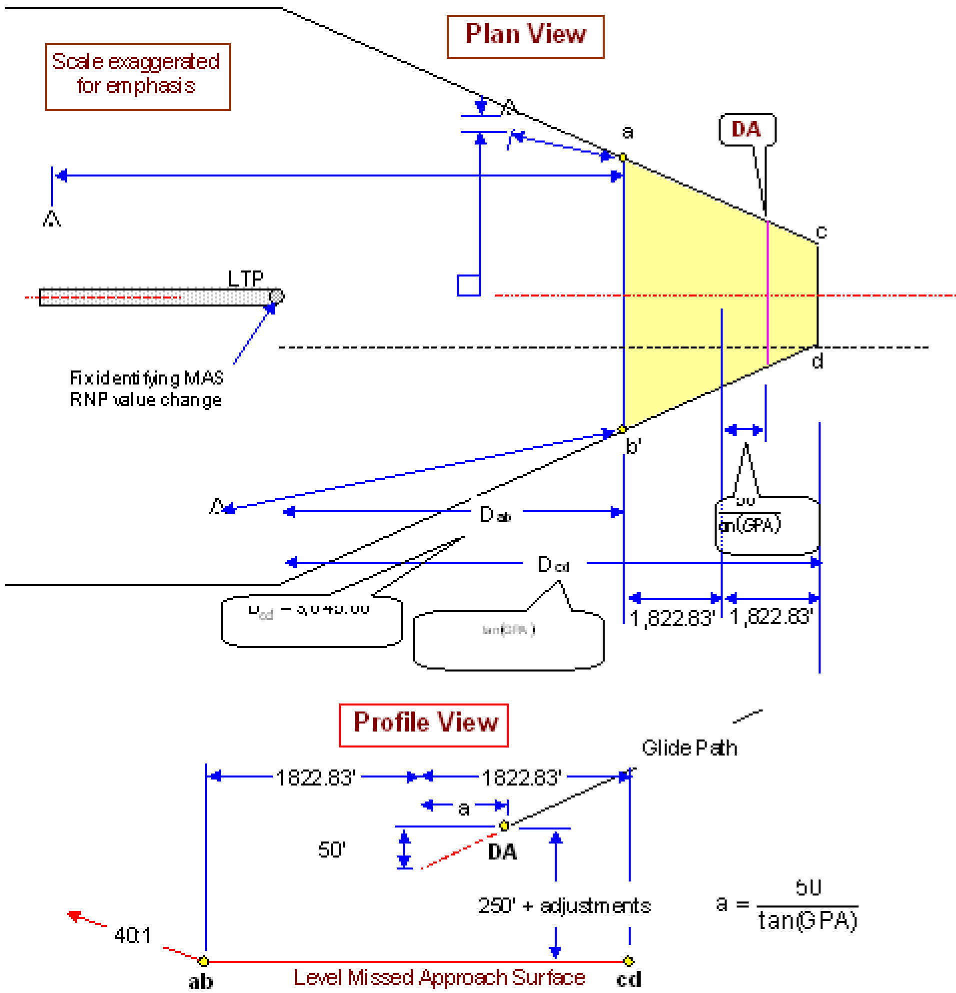
5.2.1 Length And Width.

A level surface overlies the area between cd and ab (see figure 5-5). The level surface accounts for possible along track errors inherent with LNAV/VNAV. Calculate the distance (D_{cd}) from the LTP to the cd line, and the distance (D_{ab}) from LTP to the end of the level surface (ab line), using the following formulae:

$$D_{cd} = \frac{DA\,(\text{above ABSL}) - TCH}{\tan(GPA)} - \frac{50}{\tan(GPA)} + 1{,}822.83$$

$$D_{ab} = D_{cd} - 3038.06$$

Figure 5-5. Level MA Surface



5.2.2 MA Level Surface Obstacle Clearance.

A MA LEVEL OCS overlies the area. The height of the MA LEVEL OCS is determined by the formula:

$$h = DA(\text{above ASBL}) - (ROC + \text{Adustments})$$

Where h = the height of the OCS above ASBL

(add RWT elevation to convert to MSL elevation)

If the OCS is penetrated, raise the DA the amount of the penetration. Round the result to the next higher 20-foot increment.

5.3 40:1 SURFACE.

5.3.1 Length

The 40:1 surface begins at the ab line. Terminate the 40:1 OCS at an elevation corresponding to the en route ROC below the missed approach altitude. Calculate surface rise to the obstruction position based the shortest distance from the obstruction to the ab line (see figure 5-3).

5.3.1 **a. If the 40:1 OCS terminates** prior to the clearance limit, continue the evaluation using a level OIS at the height that the 40:1 OCS was terminated.

5.3.1 **b. If the clearance limit** is reached before the 40:1 OCS terminates, continue a climb-in-hold evaluation at the clearance limit.

5.4 OBSTACLE CLEARANCE.

Where obstructions penetrate the OCS, identify the obstruction with the greatest penetration. Increase the DA by the value ($DA_{adjustment}$) calculated by applying the following formula:

$$DA_{adjustment} = \frac{(40 \times p) \times GPA}{102}$$

Where p = amount of penetration in feet

When operationally feasible, a climb gradient (G) in feet per NM may be specified to mitigate the surface penetration in lieu of increasing the DA. This option requires flight standards approval. To calculate the minimum required climb gradient, use the following formula:

$$G = \frac{a - b}{0.76D} \quad \text{Example : } 387.95 = \frac{4349 - 2120}{0.76 \times 7.56}$$

Where a = Obstruction MSL Height

b = Decision Altitude (MSL)

D = Shortest distance (NM) from obstruction to $\underline{ab}$ line

5.5 MISSED APPROACH CLEARANCE LIMIT ALTITUDE.

5.5.1 Straight Missed Approach Procedures.

Use TERPS paragraphs 274b and d to establish the charted missed approach clearance limit altitude. Use TERPS paragraph 274c to determine if a climb-in-holding evaluation is required.

5.5.2 Combination Straight/Turning Missed Approach Procedures.

Use TERPS paragraphs 277d and f to establish the charted missed approach clearance limit altitude. Use TERPS paragraph 277e to determine if a climb-in-holding evaluation is required.